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RESTRICTED CIRCULATION

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Agricultural Memorandum No 801
by J B Tyldesley

Forecasting Septoria in England and Wales

1. Introduction. Agricultural Memorandum 751 gave the background to the relation between Septoria and weather. Six years' disease data were compared with an index based on runs of wet days and relative humidity. Results were encouraging, but it was seen that they required to be checked in other areas. This has now been done, with the result that ideas both on the critical time of year for infection, and the best weather index, have been modified.

2. Disease data. The results of the National Leaf Disease Survey for the eight ADAS regions were used. In the last stages of the work the 1975 results became available, augmenting the 1970-74 figures used earlier.

3. Meteorological data. Initially the following stations were used in each region:

South-west: Exeter, Filton, Boscombe Down.
South-east: Manston, Farnborough.
West Midlands: Shawbury, Elmdon.
Wales: Valley, Cardiff.
East Midlands: Watnall, Manby.
East: Honington.
Yorks/Lancs: Squires Gate, Finningley, Leeming.
North: Acklington, Carlisle, Leeming.

Later three more stations were added; Plymouth in the South-west to give a better geographical coverage, and Brooms Barn and Morley St Botolph in the East to reduce the randomness inherent in assessing summer rainfall at a single station. Manby closed during 1974 and was substitued by Cranwell.

4. Rainfall and humidity index. For each station, the number of days satisfying the infection criteria of King were counted, and correlations with disease obtained, exactly as described in section 3 of Ag Mem 751. The results when assembled looked decidedly erratic, partly due to the erratic nature of summer rainfall itself at individual stations, and partly because a mere five data-pairs were used in each correlation. It was also noticed how often the 0900 hours relative humidity hung about the critical value of 90%. In an extreme case, 90% RH at 0900 on the middle day of seven rainy days could validate them all, while with RH of 89% they would all be thrown out.

As a first step towards reducing this scatter, though acknowledging that there are better ways of combining correlation coefficients, the coefficients were averaged first by regions and then overall. The results are shown in table 1. In this table, the regions are ordered with the areas of highest average disease over the five years at the top.

Table 1. Correlations of critical days (after King) with disease

Region	Av % disease leaf 2	March	April	May	June	July	August
South-west	23	- 0.14	0.42	0.43	0.28	0.73	-0.74
South-east	18	0.28	-0.08	0.76	0.31	0.29	-0.19
West Midlands	17	0.19	0.22	0.55	0.76	-0.10	-0.00
Wales	16	0.23	0.26	0.76	0.86	-0.67	0.37
North	14	0.11	0.56	0.79	0.89	-0.07	0.12
Yorks/Lancs	13	0.18	0.16	0.18	0.62	0.01	-0.06
East Midlands	11	- 0.06	0.08	0.35	0.48	0.44	0.62
East	11	0.11	0.20	0.57	0.56	0.14	0.02
Average, 8 regions		0.11	0.20	0.57	0.56	0.14	0.02

Table 1 confirms the belief of pathologists that May and June are the important months for infection, but the correlations are not high enough to be the basis of a satisfactory prediction.

5. Indexes of rainfall alone. The difficulty in combining humidity satisfactorily with the rainfall data, mentioned above, led to the thought that most periods of rain are accompanied and followed by a period of high humidity. Light falls would be unlikely to produce the necessary splash for spore dissemination, so only days with 1mm or more ("wet days") were counted. Correlations with disease were obtained as before. As it became clearer that May and June are the important months, efforts were made to narrow down the critical period by using half-months combined in various ways. The results are given in table 2.

Table 2. Correlations of "wet days" with disease

Region	March	April	1st half May	all May	2nd half May	2nd ½ May + 1st ½ June	May + June	1st half June	All June	2nd half June	July	August
South-west	0.26	0.61	-0.19	0.23	0.43	0.37	-0.09	0.27	0.07	-0.44	-0.56	-0.59
South-east	0.04	-0.24	-0.29	0.25	0.66	0.64	0.45	0.50	0.40	-0.00	-0.85	-0.05
West Midlands	0.27	0.78	0.69	0.78	0.55	0.82	0.95	0.65	0.85	0.81	-0.19	-0.40
Wales	0.10	0.18	-0.01	0.44	0.63	0.75	0.82	0.77	0.86	0.71	-0.90	-0.64
North	-0.53	0.40	0.98	0.85	0.62	0.62	0.76	0.52	0.54	-0.14	0.45	-0.41
Yorks/Lancs	0.11	-0.10	0.97	0.87	0.89	0.93	0.95	0.78	0.89	0.16	-0.24	-0.27
East Midlands	0.35	0.28	0.77	0.87	0.78	0.77	0.77	(0.58)	(0.39)	(-0.54)	(-0.29)	(-0.32)
East	0.54	-0.08	0.85	0.84	0.81	0.75	0.83	0.42	0.17	-0.47	-0.25	-0.44
Average, 8 regions	0.14	0.09	0.47	0.64	0.67	0.71	0.68	0.56	0.52	0.01	-0.35	-0.39

The table strongly suggests that May and June, and particularly the last two weeks of May and the first two weeks of June, is the critical period. However, it has to be admitted that this method of looking for the critical period is an inefficient one. Seasonal persistence of weather is often a reality, and in particular the late May-early June period is well known (for instance from studies of weather for grass conservation) to be a natural weather period and one of the driest in the year. An association of weather in part of this period with disease does not necessarily imply that the influence was direct. It may merely imply that the weather of that part is closely associated with weather of another part of the period, which in turn is active in promoting the disease. It follows that to understand causes, there is no substitute for monitoring the progress of the disease in the crop through the growing season.

Taken overall, slightly better correlations were obtained for disease with "wet" days (table 2) than with "critical" days (table 1), so it appears that the complication of introducing humidity at 0900 hours is not justified by the results.

A puzzling feature of table 2 is the frequent appearance of negative (though not large) correlations as the summer wears on. The disease assessment is done in July and by August much of the crop has been harvested, so the cause can hardly be a direct effect of weather on the crop. Is it possible that wet spells in May and June are regularly associated with dry spells later in the summer? Or does dry weather close to harvest affect the assessment of disease in some way?

On the whole, the lower the incidence of Septoria in a region, the higher the correlation with summer weather is. This reflects the obvious difficulty of predicting the incidence of a disease in an area where it is more or less endemic.

One millimetre of rain is quite a modest fall. If it comes as light rain or drizzle over an extended period, it may not produce the splash necessary for the spread of spores. Correlations with days with 5mm or more of rain were therefore made, just in the same way as with 1mm days except that March, April and August were now omitted as unlikely to be important. The results are given in table 3.

Table 3. Correlations of "5mm" days with disease

Region	1st half May	2nd half May	2nd ½ May + 1st ½ June	1st half June	all June	2nd half June	July
South-west	-0.30	0.65	0.75	0.65	0.41	-0.69	-0.06
South-east	0.28	0.10	0.63	0.67	0.40	0.37	-0.66
West Midlands	0.34	0.24	0.85	0.78	0.67	-0.60	-0.08
Wales	0.02	0.25	0.64	0.74	0.40	-0.26	-0.73
North	0.83	0.51	0.81	0.46	0.29	-0.37	-0.77
Yorks/Lancs	0.21	0.40	0.93	0.80	0.63	-0.31	-0.33
East Midlands	0.59	0.23	0.61	0.52	0.01	-0.36	-0.28
East	0.48	0.11	0.67	0.55	0.63	0.54	0.24
Average, 8 regions	0.30	0.31	0.74	0.65	0.43	-0.21	-0.33

The correlations have much the same patterns as for the 1mm days in table 2. The main difference is rather lower correlations in May, the first possible time for an "early warning".

At this point in the investigation the 1975 disease results became available, and data considered so far were reworked, with the addition of the extra stations mentioned at the end of section 1 and the 1975 information. Attention was concentrated on the May/June period, and as the previous conclusions were not disturbed by the

additional data, the results are given in summary only in table 4.

Table 4. Correlations of rain days with disease, incorporating 1975 data and additional stations

	1st half May	2nd half May	2nd ½ May + 1st ½ June	1st half June	2nd half June
Average, 8 regions, 1mm days	0.37	0.75	0.73	0.52	0.42
Average, 8 regions, 5mm days	0.28	0.41	0.71	0.58	0.19

6. Index of rainfall and sunshine. If say 2mm of rain early in the day is followed by 12 hours of bright sunshine, then it is possible that the day will not be so favourable for infection as it would be if the rain were followed by dull weather. An attempt was made to allow for this. Using daily rainfall and sunshine totals, it is not possible to tell whether the rain fell by day or by night, nor if the rain preceded the sun or vice versa. Only crude methods were therefore thought appropriate. In each region average values of potential evapotranspiration and sunshine were found from MAFF Technical Bulletin No 16. For near-average sunshine, the daily PET was assumed to vary with sunshine in the same way as monthly means, as indicated by the "x-coefficient" also given in the Bulletin. This relation was tailed-off to give a low PET value at zero sunshine. In this way the daily evaporation E at each site was estimated, and combined with the rainfall R to give R-E. Only values of R-E which exceeded 1mm were considered effective for infection, and these were counted. The procedure was laborious, so it was tried first in two regions; Yorks/Lancs where the plain rainfall approach had been very successful, and the South-west where infection is regularly high and it had not done so well. Correlations with disease were calculated as before, and the results are shown in table 5.

Table 5. Correlations of days with 1mm or more of rain after adjustment for evaporation, with disease

Region	with adjustment or not	1st half May	2nd half May	2nd ½ May + 1st ½ June	1st half June	2nd half June
South-west	yes	0.37	0.58	0.71	0.57	0.70
	no	0.03	0.57	0.57	0.40	0.70
Yorks/Lancs	yes	0.07	0.63	0.71	0.59	0.03
	no	0.51	0.88	0.94	0.77	0.35

The adjustment for evaporation degraded the previous results in Yorks/Lancs, so was not pursued further in the four regions with lowest overall disease incidence. There was an apparent slight increase in correlation when the adjustment was made in the South-west. The procedure was therefore carried through in the three next most disease-prone regions; the South-east, West Midlands and Wales. As table 6 shows, the results were not encouraging, so they are given in summary only.

Table 6. Correlations of days with 1mm or more of rain after adjustment for evaporation, with disease, in the four most disease-prone regions

	1st half May	2nd half May	2nd ½ May + 1st ½ June	1st half June	2nd half June
with adjustment	0.24	0.39	0.72	0.59	0.52
without adjustment	0.25	0.68	0.69	0.46	0.66

It seems that there is no consistent advantage in including the effect of sunshine in the way done here, though the possibility remains that a less crude approach might be more effective.

7. A proposed forecast method

It appears that although there are sound reasons for believing that the inclusion of humidity or sunshine might improve the efficiency of rain days as a predictor of Septoria infection, in practice no advantage is gained and there is a decided loss of simplicity. Once this is accepted the problem boils down to the selection of the best calendar period, and the best rainfall limit, for counting rain days. To help with this, separate plots were prepared of rain-days against infection, for late May and early June, for 1 and 5mm rainfall limits, and for the four most and four least disease-susceptible regions. All this was done on tracing paper, so that the plots could be appropriately compared or combined. Fig 1 shows the late May plots for 1mm rainfall limits, these having been chosen for illustration because they turned out to be the most useful for prediction. In this connection, it was interesting to see that size of correlation coefficient does not provide a complete guide. Behind the correlation coefficient lie ideas of linear dependence and symmetrical scatter which are not always verified in practice. Thus, fig 1 suggests that in the present case there is no dependence of disease on rain-days for small number of rain-days, though in these conditions the disease is lower in the north and east of the country than elsewhere. For greater numbers of rain-days, disease increases generally. However the points are scattered, with a strong suggestion of an upper envelope. The interpretation is that rain-days in late May give a potential for the increase of the disease; which may or may not be realised, according to other factors.

Fig 1 has been lightly ruled with some proposed categories of disease incidence, and the corresponding rain-day limits. In the regions where Septoria is endemic, the "light infection" category is more broadly defined than elsewhere. An examination of those points where the disease level fell well below expectation, showed that some of them represented occasions when, contrary to the usual pattern, a wet second half of May was followed by a dry first half of June. An allowance for this is given at the bottom of table 7 which gives the proposed forecast rules.

Table 7. Proposed rules for forecasting Septoria, using number of days with 1mm or more of rain in the second half of May and the first half of June.

Group 1: South-west, South-east, West Midlands and Welsh regions

No. of wet days 2nd half of May	3 or less	4	5 or more
forecast infection, %	Light (less than 10%)	moderate (10-20%)	heavy (more than 20%)

Group 2: North, Yorks/Lancs, East Midland and East Regions

No of wet days 2nd half of May	3 or less	4	6 or more
forecast infection, %	light (less than 5%)	moderate (5-20%)	heavy (more than 20%)

For both groups, if the first half of June has 2 or less wet days, reduce the forecast category by one: ie heavy becomes moderate, and moderate becomes light.

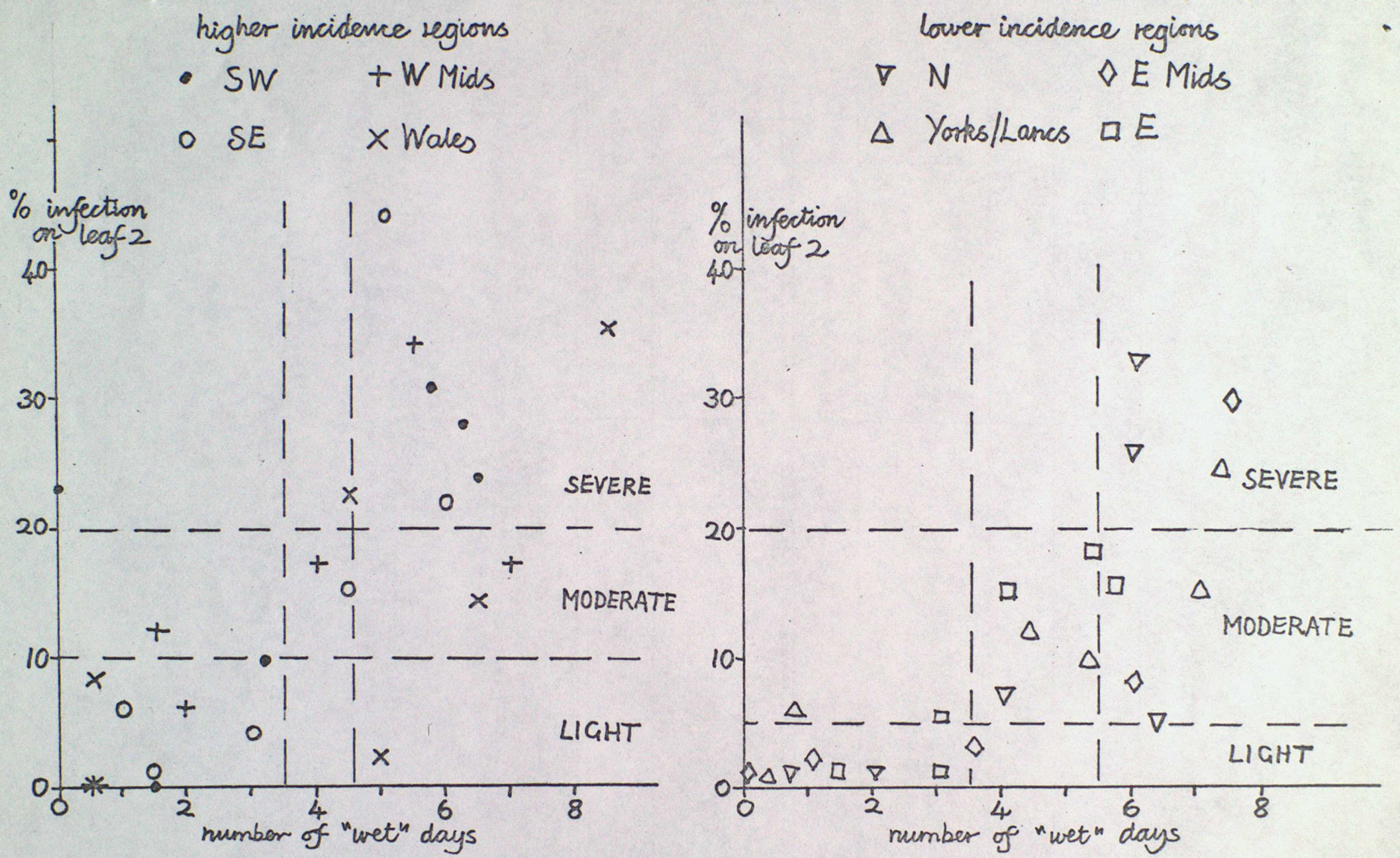

Fig 1. Relation between number of days with 1mm or more of rain in the second half of May, and % leaf area affected by Septoria. The disease assessment is made when the grain is at the milky ripe stage, 4-6 weeks before harvest.

The scheme of table 7 envisages a first forecast or early warning at the end of May, and a final forecast at mid June. If light, moderate or severe outbreaks are coded as 0, 1 and 2 respectively, then the difference between actual and forecast ratings can be tabulated, as in table 8. Note that the six years used here are those that gave rise to the forecast rules. As more years' data are accumulated, it will be very desirable to make an independent test.

Table 8. Actual minus forecast Septoria ratings

Region	rating difference, first forecast					rating difference, final forecast				
	+ 2	+ 1	0	- 1	- 2	+ 2	+ 1	0	- 1	- 2
South-west	1	1	4	0	0	0	2	3	1	0
South-east	0	2	4	0	0	0	3	3	0	0
West Midlands	0	2	3	1	0	0	2	4	0	0
Wales	0	2	2	2	0	0	2	3	1	0
total, group 1	1	7	13	3	0	0	9	13	2	0
North	0	0	5	1	0	0	1	4	1	0
Yorks/Lancs	0	1	4	1	0	0	1	5	0	0
East Midlands	0	0	4	2	0	0	0	5	1	0
East	0	1	4	1	0	0	1	5	0	0
total, group 2	0	2	17	5	0	0	3	19	2	0

The best results are for group 2 and for the final forecast, as would be expected. Only in one case, on the first forecast, is the prediction wrong by two categories. At least half the forecasts are correct, the remainder being one category out. For group 2, the final forecasts are more than three-quarters correct.

8. Application. It is suggested that the method described in the previous section might be used, in combination with information from plant pathologists on the progress of crops and disease in each region, to produce forecasts of Septoria on a trial basis. In each Region a handful of rainfall stations should be used, designed to sample the main wheat-growing areas, as well as the inherent variability of summer rainfall.

Any comments or suggestions on this paper should be referred to the author.

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April 1976